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INDIVIDUAL DIFFERENCES IN THE PROCESS OF SOLVING PROBLEMS: COMPUTER FLOW CHARTING AND RELATIVE MOTION TASKS

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by

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BRIEF

This was an exploratory study aimed at developing methods and hypotheses about how individuals solve complex problems involved in Navy instruction. Particular attention was given to instances where individuals were required to solve problems with requirements that were inconsistent with their most highly developed skills and aptitudes, e.g., individuals with high verbal aptitude required to solve problems which were mainly mathematical in nature.

For only three of the six types of problems used in the study was it possible to observe and categorize the problem-solving activity. One purpose of this study therefore--comparison of problem-solving activity across tasks of different types--could not be achieved. Among three types of problem for which processes were observable and could be categorized, the processes for one, Concept Attainment, were sufficiently different from the other two to make clear that problem-solving strategies vary from task to task and may even be specific to a single type of task.

For two tasks, Flow Charting and Relative Motion problems, responses were categorized in a manner descriptive of the processes used in working on them. Major findings were the marked differences in approaches or strategies for solving these problems by groups differing in verbal-mathematical aptitude patterns. Different training methods will need to be developed for these groups to maximize efficiency in teaching this kind of problem solving. Learning progress was so poor for low aptitude groups that special justification is needed for attempting to instruct this group in this kind of task. Special materials and very likely considerably more time will be required. The time required to code and analyze responses in this kind of study require that further work in this area be deferred until a properly programmed and equipped computer is available for keeping track of trainee responses.

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FIGURES (Cont'd.)

INDIVIDUAL DIFFERENCES IN THE PROCESS OF SOLVING PROBLEMS: COMPUTER FLOW CHARTING AND RELATIVE MOTION TASKS

A. Purpose of the Study

This was an exploratory study aimed at developing methods and hypotheses relating to how individuals go about solving complex problems. It was desired to determine the similarities and differences among problem solving activities of six different types of tasks. Problem solving activities were observed and recorded for these tasks. Attention in this study is focused on tasks which involve logical, mathematical, or symbolic operations.

As the first step in developing hypotheses about the processes, it is necessary to learn how problem solving responses of individuals possessing optimum relevant aptitudes differ from those of individuals not possessing such aptitudes.

Gagné (1965) has tentatively described a series of relationships between problem solving and other learned capabilities, and aptitudes. His system places stimulus recognition learning (i.e., ability to respond to the presence or absence of a single stimulus) at the bottom of a hierarchy, and problem solving at the top, as follows:

Problem Solving
Learning of Principles (relationships between concepts)
Learning of Concepts (similarities between stimuli; i.e., "abstractions")
Learning of Multiple Discriminations (differences between stimuli)
Verbal Associations
Chaining (verbal and motor responses; response becomes stimulus and evokes new response, etc.)
Response (motor and/or verbal) to stimulus
Stimulus Recognition Learning

Problem solving is described in part as a strategy for the learning and deriving of new principles, i.e., principles not available for learning at the level indicated for principles below problem solution. In problem solving the learned capabilities existing within other levels, especially concepts and multiple discriminations, are mobilized to promote the derivation of principles. If some of the necessary capabilities within other levels have not been learned, the individual may be forced to acquire them before he can proceed with deriving new principles. The individual will, furthermore, base the acquiring of new capabilities on those which are already available to him. If he has strong capabilities in verbal association, he will have high verbal aptitude scores and will tend to employ word attributes and information in the form of sentences in understanding and deriving concepts and principles. Similarly, certain motor and symbolic capabilities may sometimes be related to

mathematical learning of relations between work, weights, shapes, and the mechanical aspects of physics. An individual using such symbol and motor capabilities in learning mathematical relations may tend to analyze new mathematical tasks in terms of analogies peculiar to certain mechanical relationships. Learned capabilities which are below the top level of problem solving support this activity and will be referred to in this report as "supporting types of learning."

Analysis of a specific type of problem solving task based on such a system of learning should permit the detection of learning difficulties within the structure of the aptitudes and existing capabilities of the individual. It should be possible to relate required verbal capabilities, multiple discriminations, and concepts with the existing capabilities of the individual based on his aptitude patterns and achievements.

The current study was designed to employ such a system in developing a technique to diagnose the capabilities and weaknesses of specific aptitude profile groups in solving specific types of problem tasks (taken one at a time) through observing the process of deriving problem solutions. Special attention was given in this study to the learning requirements of individuals high in verbal aptitude and low in mathematical aptitude in the approach to problem solving tasks of a mathematical and logico-symbolic type. Ultimately, information should come from this line of research which can be used to restructure learning materials for this group of individuals, and to facilitate their learning.

Because the study of problem solving requires intensive observation, large amounts of data are generated and the number of experimental subjects for whom total data can be processed without the use of a highly specialized computerized installation is necessarily small. This study is an intensive study of ten subjects grouped into four experimental groups (described later).

B. The Tasks

The six tasks for this study were chosen for their relevance to Navy training problems and to provide variation in required solution operations and in input or stimulus conditions. The tasks are listed below:

Computer Program Flow Charting
Relative Motion (of ships)
Number Base Arithmetic
Concept Attainment
Reading Comprehension
Hypothesis Evaluation

Due to the nature of some of the tasks and the limitations of a manual method of recording task process responses of individuals as they worked on the problems, only three tasks, Computer Flow Charting, Relative Motion, and Concept Attainment produced data which were usable for the

process analysis.[1] An exhaustive or highly developed system for classifying task process responses for Concept Attainment could not be achieved within the interest of this study; and hence task process analysis results to be presented in detail are limited to the Computer Flow Charting and Relative Motion tasks.

1. The Computer Flow Charting Task

This task required the trainee to design computer flow charts for doing simple tasks in arithmetic and logic. Instruction for developing the charts was provided by a specially constructed manual.

The inputs involved reading. The task required the use of familiar algebraic symbols to perform operations both familiar and unfamiliar in algebra, the use of unfamiliar symbols to indicate sequences of logic and arithmetic; the drafting and modifying of successive drafts; and the evaluation of previous drafts by reading operations and sequences from them. The major response mode involved operations in symbols and logic.

2. The Relative Motion Task

In this task the trainee was required to solve exercises involving relative motion of ships. Use of graphic aids, tables, and tools was explained and practice provided before beginning the exercises; tables and reference information on use of the tools were also available to the trainee during the exercise. The major response mode involved operations in arithmetic and spatial analysis.

C. Method

The trainees were male undergraduate students at San Diego State College. Each student was employed as an experimental trainee for a block of four-hour sessions, once a week for seven weeks. A new task was introduced each week with the exception of Flow Charting, which required two sessions. The major methodological problems were developing methods of observing, recording, and classifying the operations the subjects were actually performing as they worked at solving the problems. Two observers were present at all problem solving sessions. Each kept a detailed record. Subjects were requested to think aloud and a tape recording was made of their remarks as well as of other verbalizations by the subjects and the observers.

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[1] Descriptions of Concept Attainment and the three remaining tasks (from which usable process data could not be obtained) are given in Appendix A.

Symbolic-mathematical and verbal aptitudes were measured by eight aptitude tests.[2] Based on aptitude scores, four subgroups of trainees were identified having aptitude patterns expected to be related to task process patterns of problem solving activity and involving a minimum of overlap.[3] The subgroups are as follows: A group having high aptitudes in mathematics and symbol operations and somewhat low aptitudes for verbal tasks (High Mathematics group); a group having high verbal aptitudes and somewhat lower ones in the mathematics and symbol operations area (High Verbal group); a third group of trainees who were intermediate on both mathematics and symbolic operations and on verbal aptitudes (Intermediate group); and a fourth group in which the trainees had relatively low scores on both mathematics and symbol operations aptitudes and on verbal aptitudes (Low group). The groups are not as distinct as one would wish. Any differences found should therefore be considered minimal.

D. Classifying Responses in Problem Solving: A Tentative Method of Analyzing Task Processes

The item-by-item account of the trainee's activities provided by the subjects and observers were the raw data for the analysis.

It was found for the Flow Charting and the Relative Motion tasks that trainee responses could be classified in five areas of problem solving: (1) Obtains Task Inputs, (2) Obtains Technical Instruction, (3) Operates, (4) Rereads or Reviews Work Product, and (5) Evaluates Work Product. A sixth area of activity, Finishes Work Product or Work Product Cycle was also used to account for terminating an exercise (see area descriptions in Table 1).

In completing tabulations, the Operates activities were subcategorized into Initiates and Develops Solution, Modifies Work Product, and Drafts Trial Aspect of Work Product. For each of these activity areas a number of specific activities were identified and defined. A number of these activities were common to the Computer Flow Charting task, the Relative Motion task, and the Concept Attainment task. Some were unique to one task or another. The specific activities of the task process in Flow Charting are given in Table 2. These activities are referred to as "Task Process Activities" throughout the remainder of this report.

E. Results of Task Process Analysis

1. The Computer Flow Charting Task

The percentage of time allocated to each of the task process behavior areas, e.g., Obtains Task Inputs, Obtains Task Instructions, Operates,

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[2] The tests are listed in Appendix A.

[3] The subgroup aptitude profiles are given in Appendix B.

TABLE 1

Description of Task Process Activity Areas

Obtains Task Input	Reads, studies, or examines exercise to be worked on.
Obtains Technical Instruction	Reads manual, searches manual for specific items of technical information; tries to obtain information or practice to enable self to use task-specific tools or operation required for completion of solution.
Operates (Performs step toward completion of work product)	Initiates and develops, modifies, deletes and begins over, or makes trial notes for part of solution.
Rereads or Reviews Work Product	Reads sequence of instructions in Flow Chart task as computer would read them; Reads over solution in Relative Motion task. Learns special methods or ways of reading solution.
Evaluates Work Product	Conducts various tests to determine whether solution is really an answer to exercise. Repeats solving and checks to determine whether second answer is same as first; mentally repeats operations in solution while tracing operations with finger.
Finishes or Terminates Work Product	Finishes solution with or without explicit mention; finishes draft cycle or iteration.

TABLE 2

Classes and Activities Used to Describe the Process of Problem Solution in Designing Flow Charts

Class	
Code	Activity
Obtains Task Inputs	
T-1	Scans input information
T-2	Reads exercise statement
T-3	Obtains specific task aspects or facts
Obtains Technical Instruction (Examines Manual)	
I-1	General reading
I-2	Reads specific example or passage
I-3	Asks instructor about passage or information
I-4	Information received from instructor
I-5	Uses index to manual
I-6	Instructor refers trainee to index
I-7	Instructor refers trainee to passage
I-8	Examines chart for previously completed exercise
Operates (Performs Step Toward Completion of Work Product)	
Op-1	Initiates product (i.e., notes or chart)
Op-2	Elaborates product
Op-3	Modifies product
Op-4	Deletes from product or discards as draft
Op-5	Starts over
Op-6	Makes working notes or design sketches
Op-7	Verbalizes preliminary notes or sketches
Op-8	Recopies chart
Rereads or Reviews Work Product	
R-1	Reads product silently (frequently combined with E-4)
R-2	Manifests verbalization
R-3	Traces (design) product with finger or pencil
R-4	Uses technical aids specific to product task
R-5	Reads with translation aided by instructor

(Table continued on next page)

TABLE 2 (continued)

Evaluates Work Product	
E-1	Makes independent check (repeats to check outcome)
E-2	Numerical check
E-3	Graphic check
E-4	Logical check (Reexamines current product; frequently combined with R-1, above)
E-5	Requests instructor evaluation
E-6	Receives instructor evaluation
E-7	Instructor tells trainee to evaluate product
E-8	Evaluation refused by instructor (as required by task or exercise)
Finishes or Terminates Task	
F-1	Finishes a draft or cycle in solution
F-2	Finishes product; termination referred to in protocol
F-3	Finishes proceeds; no mention of terminating

for each aptitude group for the Flow Charting task is presented in Table 3. These scores are average percentages of the total time trainees in each aptitude group spent working on the Flow Charting task.

The first point to note from Table 3 is the small amount of time (a mean of 8.9 minutes) spent on each exercise by the High Mathematics group. Further, the quality of the solutions to the Flow Charting exercises, as well as the number worked on (Figures 1 and 2) follow the same trends. The High Mathematics group stands out clearly from the rest. As will be seen shortly, the larger mean amount of time (Table 3) spent by every group except the High Mathematics group appears to be the result of difficulty in learning the technical information needed to go on to develop solutions to each exercise.

The second major finding to be noted from Table 3 (and Figures 5 and 6) is the poor record of the Low Aptitude group; a third, the considerably shorter time and smaller proportion of time spent by the High Mathematics group in obtaining technical instruction (8 per cent as contrasted with the 15, 19, and 24 per cent) expended by the Low, High Verbal, and Intermediate groups respectively.

A trend analysis was performed of the mean per cent of task process activity categories allocated in each exercise by each aptitude group. Two major patterns illustrate the differences in task process behavior among the aptitude groups (except the Low Aptitude group, which produced too few scoreable charts to be included).

It will be recalled that the category, Initiates and Develops Solution, describes an activity by which the subject is actively constructing or developing a Flow Chart design. Trends for the High Mathematics and High Verbal groups for this category are given in Fig. 3. It can be seen that the percentage of the high, not the absolute duration, of time allotted to Initiates and Develops Solution is much greater for the High Mathematics group as compared to the High Verbal group for Exercises 1, 2, 4, and 5. The magnitude of the percentage differences is on the order of 15 to 20 percentage points for those exercises, save for Exercise 3, where they are approximately the same.

When the result is supplemented by a trend analysis of the category entitled Obtains Technical Instruction (Fig. 4) it is discovered how this difference comes about. It can be noted from Fig. 4 that the High Verbal group consistently allots a larger percentage and a greater length of its time to this category than does the High Mathematics group. The category, Obtains Technical Instruction, is a major contributor to the diversion of the trainee's problem solving efforts from the Initiates and Develops Solution category. Since the definitions, symbols, and rules for the flow charting language were new to all of the trainees, it is inferred that the High Verbal trainees experienced greater difficulties in learning or retaining the information included in the technical

TABLE 3

Per Cent Time Allocations of Task Process Categories
and Total Time by Aptitude Group: Flow Charting

Aptitude Group	Task Input	Technical Instructions	Operations 1-2[a]	Operations 3-5[b]	Operations 6-8[c]	Rereads	Evaluates	Finishes	Mean Time (Minutes)
High Mathematics	15	8	37	5	11	5	8	6	8.9
High Verbal[d]	12	19	23	12	5	11	15	2	27.8
Intermediate[e]	11	24	32	17	2	3	8	3	18.0
Low[f]	18	15	19	8	15	6	14	3	26.0

[a]Initiates and Develops Solution.

[b]Modifies Work Product.

[c]Drafts Trial Aspect of Work Product.

[d]One of these two trainees attempted only four of the five exercises (see Fig. 1).

[e]One of these three trainees attempted only one of the five exercises (see Fig. 1).

[f]One of these two trainees attempted only one exercise, and the other did not complete any exercises (see Fig. 1).

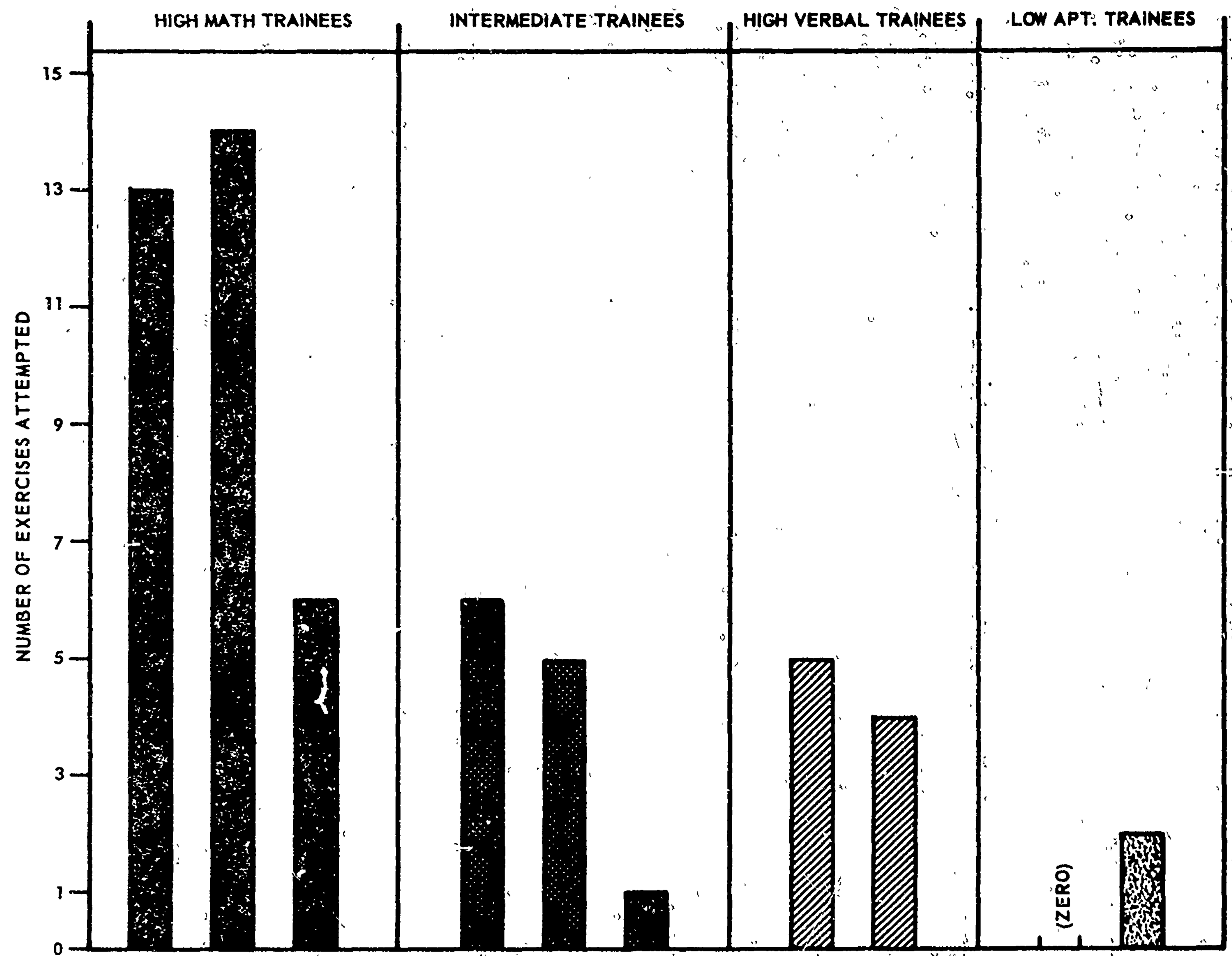

Fig. 1. Number of Flow Chart exercises attempted by Trainees within each aptitude group.

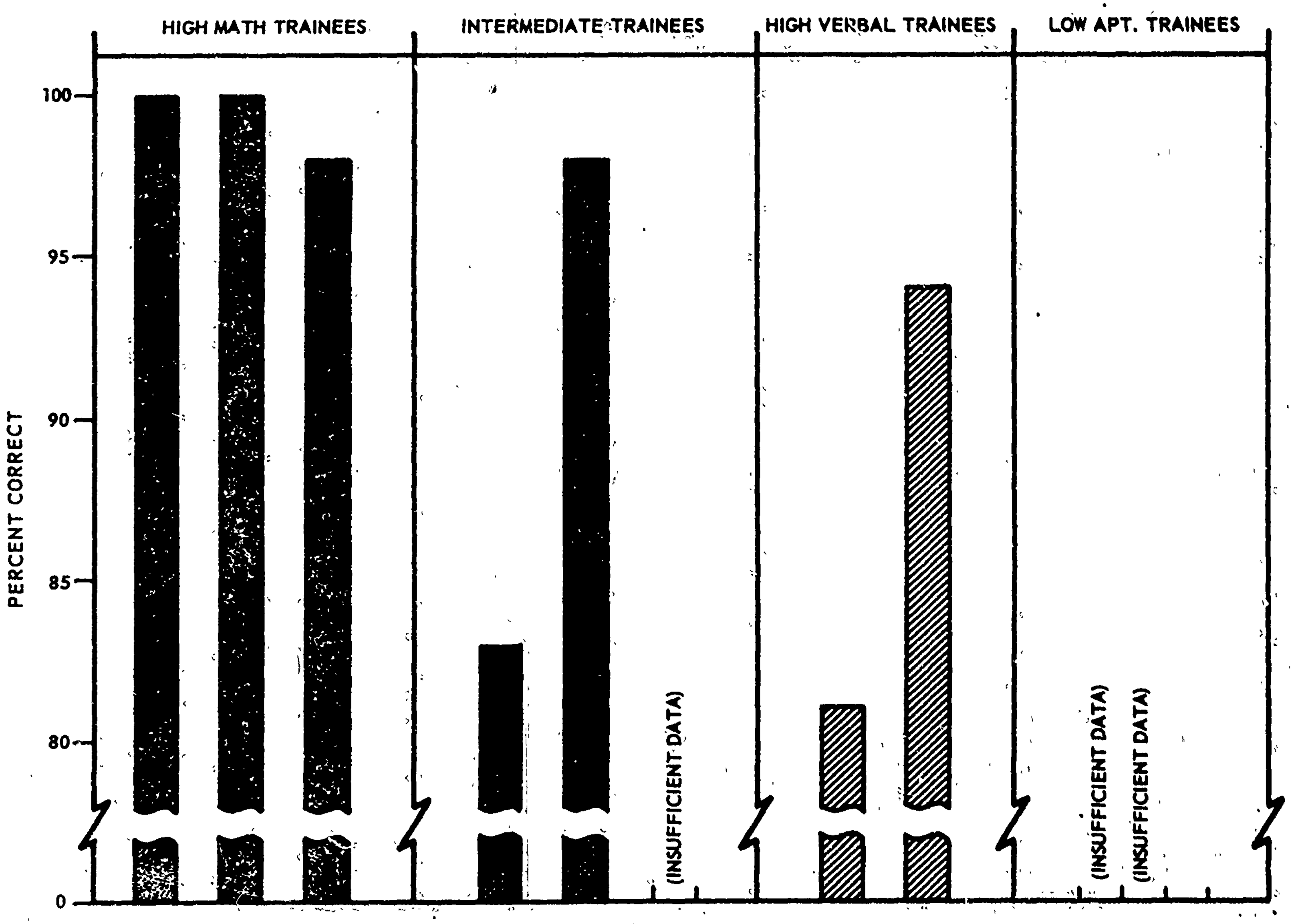

Fig. 2. Median per cent of correct Flow Chart symbols in first four exercises by trainees within each aptitude group.

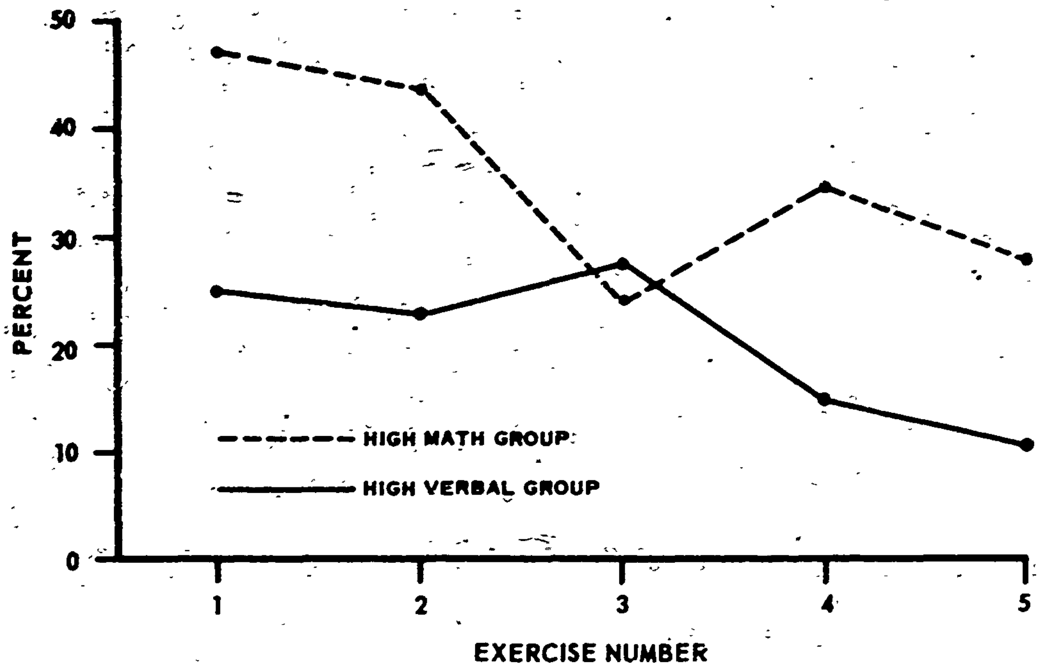

Fig. 3. Trends for Initiates and Develops Solution for Computer Flow Chart task. (Scores are mean per cent of time by exercise and by aptitude group.)

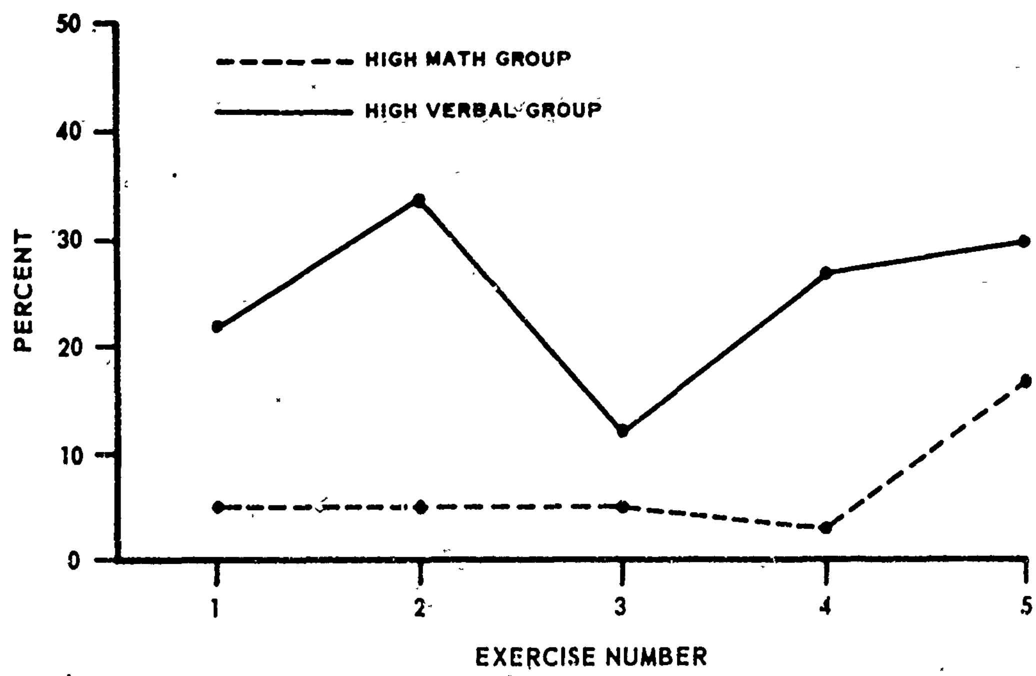

Fig. 4. Trends for Obtains Technical Instruction for Computer Flow Chart task. (Scores are mean per cent of time by exercise and by aptitude group.)

instructions and had to refer more frequently and for longer periods to this material during the conduct of the exercises.

A trend analysis for the Intermediate group (Fig. 5) further contributes to the understanding of the differences in the allocation of time to the categories of task processing. This group changes abruptly in its allocation of time from Obtains Technical Instruction to Initiates and Develops Solution. The Intermediate group quickly learns the technical information required and by the third exercise is able to concentrate on the more significant process category--Initiates and Develops Solution.

Another way of summarizing the information contained in Figures 3, 4, and 5 is as follows: All groups start out at about the same level. The High Mathematics group quickly learns the technical information needed and devotes a high proportion of its time to the Initiates and Develops Solution category. The Intermediate group takes longer to learn the technical information but by the third exercise is devoting its time to Initiates and Develops Solution. The High Verbal group has difficulty in learning the technical information and hence spends a smaller and smaller proportion (not actual duration) of its time in Initiates and Develops Solution. Implications of these findings for training will be discussed later.

2. <u>The Relative Motion Task</u>

Table 4 gives the mean per cent of time allocated to the task process categories for the Relative Motion exercises. Note how little time is spent on the Obtains Technical Instruction category by any of the groups. The quality of the solutions to the Relative Motion exercises, as well as the number worked on (Figures 6 and 7) follow the same trends. The technical information was readily learned by all groups except the Low group. Thus, all groups were able to devote relatively more time to the category of Initiates and Develops Solution. In terms of mean time spent on the exercises, the order of the groups is similar to the order for the Flow Charting exercises (Table 3), although the differences are not so large for the Relative Motion exercises.

The High Verbal group did better than in the Flow Charting exercises, and the trend analyses (Figures 8 and 9) indicate an increase in the category of Initiates and Develops Solution and a sharp decrease in Obtains Technical Instruction after the first exercise. The Low group provides a contrast. Fig. 10 indicates that the Low group achieved less than the other groups, and the Low group spent a lower per cent of time on the Initiates and Develops Solution category (39% as compared with 53%, 47%, and 45%) than the other groups (see Table 4). The trend analysis (Fig. 10) indicates a decreasing allocation to Initiates and Develops Solution, and an increase in Obtains Technical Instruction.

As noted for the Flow Charting task, the category, Obtains Technical Instruction, is a major source of diversion from the Initiates and Develops Solution category. It is inferred that the one Low aptitude

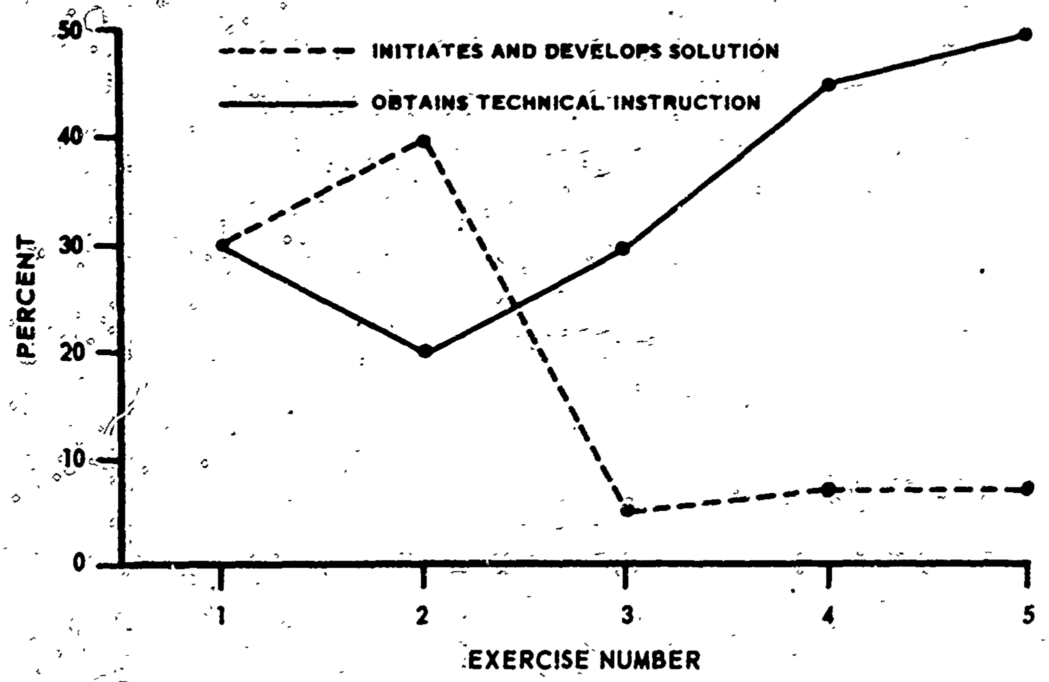

Fig. 5. Trends for allocations made to categories, Initiates and Develops Solution and Obtains Technical Instruction by Intermediate aptitude group. (Scores are mean per cent of time by exercise.)

TABLE 4

Per Cent Time Allocations of Task Process Categories and Total Time by Aptitude Group: Relative Motion

Aptitude Group	Task Input	Technical Instructions 1-9	Technical Instructions 10[a]	Operations 1-2,9[b]	Operations 3-5[c]	Operations 6-8[d]	Rereads	Evaluates	Finishes	Mean Time (Minutes)
High Mathematics	27	0	3	53	2	2	2	6	5[e]	15.3
High Verbal	25	6	2	47	3	2	1	6	3[e]	21.1
Intermediate[f]	21	4	3	45	1	2	2	4	3[e]	19.5
Low[g]	28	4	3	39	1	1	7	3	2[e]	25.6

[a]Table Reading.

[b]Initiates and Develops Solution.

[c]Modifies Work Product.

[d]Drafts Trial Aspect of Work Product.

[e]Per cent figures fail to total to 100 because some trainee pauses were uncoded.

[f]One of the three trainees attempted only four of the five exercises subjected to trend analysis (see Fig. 6).

[g]One of these two trainees attempted only three of the five exercises subjected to trend analysis (see Fig. 6).

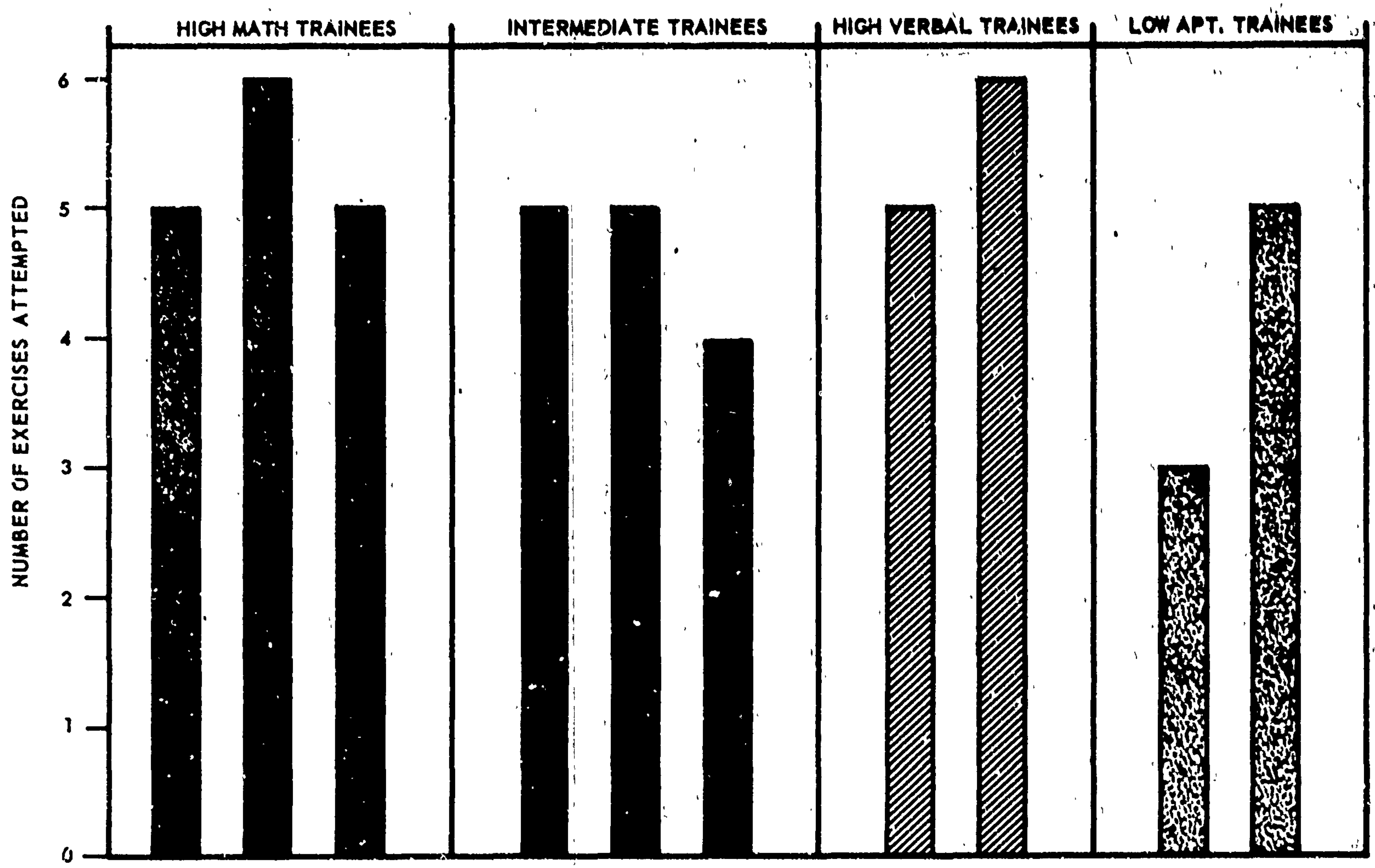

Fig. 6. Numb-r of Relative Motion exercises attempted by trainees within each aptitude group.

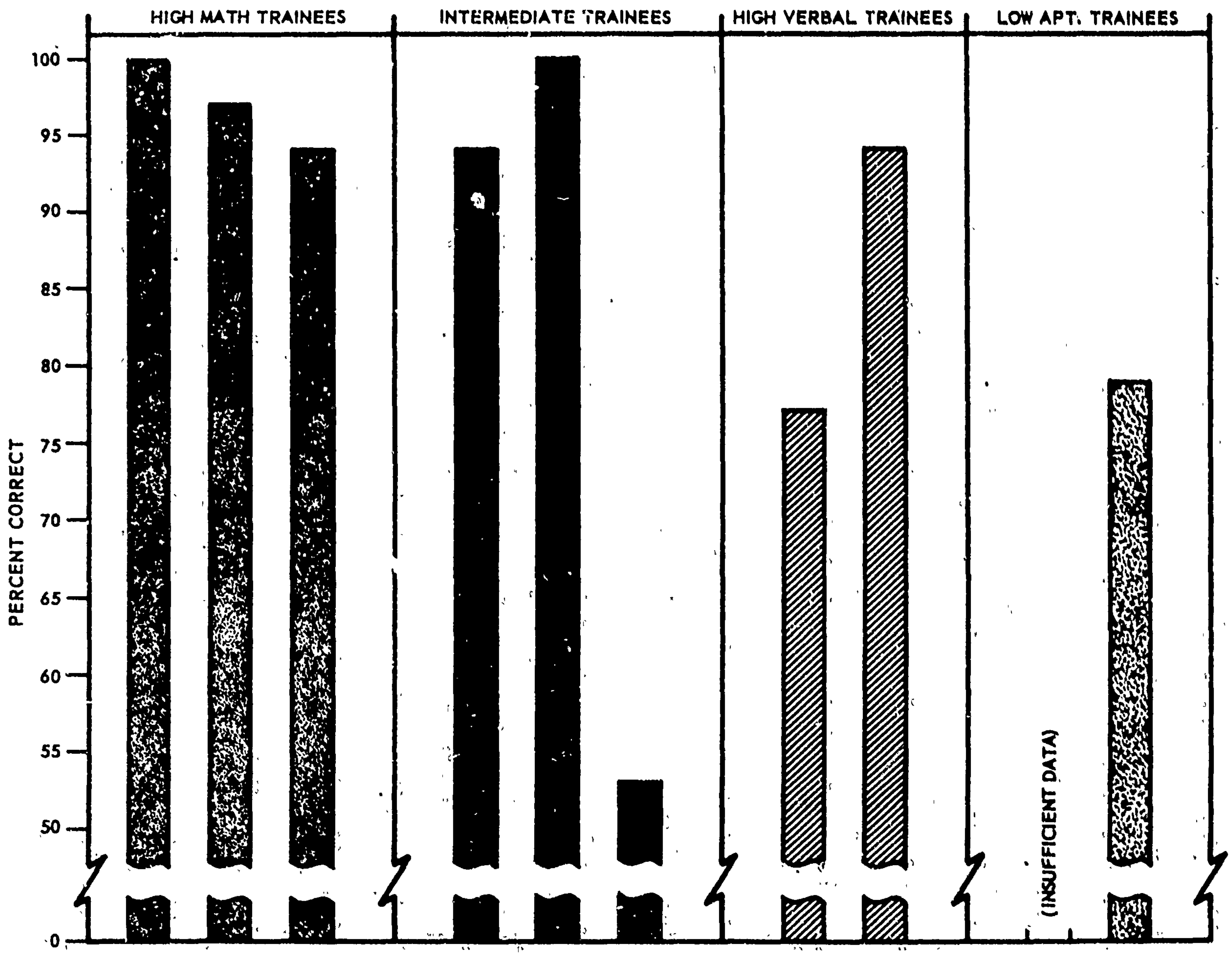

Fig. 7. Median per cent of Relative Motion achievement in first five exercises by trainees of each aptitude group.

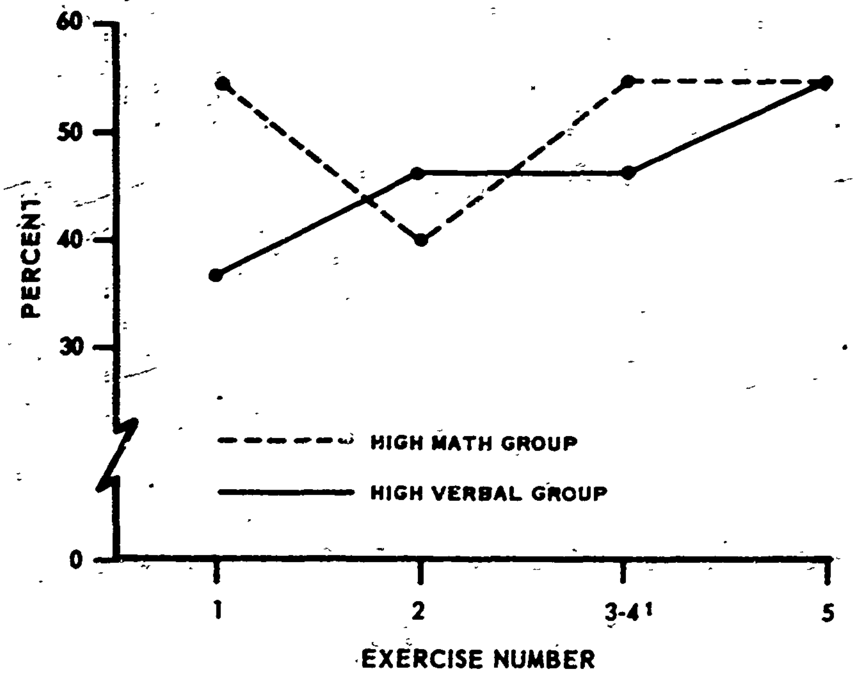

Fig. 8. Trends for Initiates and Develops Solution for Relative Motion task. (Scores are mean per cent of time by exercise and by aptitude group.)

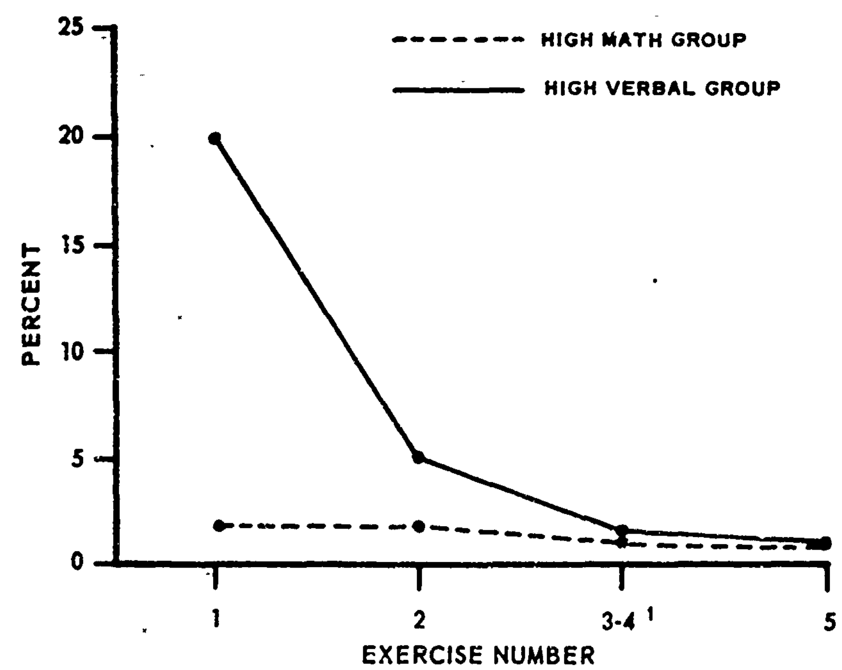

Fig. 9. Trends for Obtains Technical Instruction for Relative Motion task. (Scores are mean per cent of time by exercise and by aptitude group.)

[1] TASK PROCESS ACTIVITIES FOR EXERCISES 3 AND 4 COULD NOT BE SEPARATED

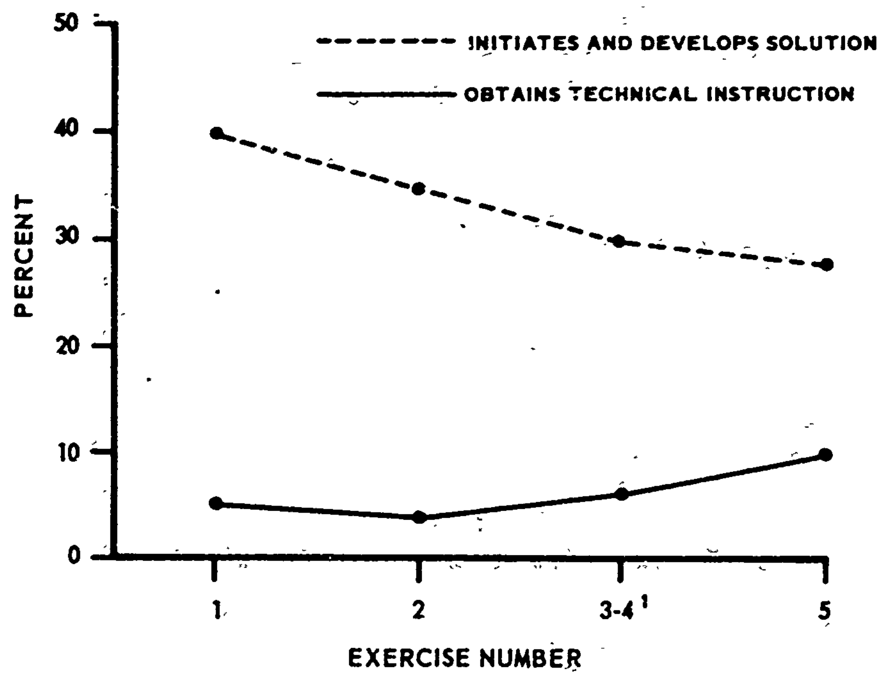

Fig. 10. Trends for allocations made to categories, Initiates and Develops Solution and Obtains Technical Instruction by Low aptitude group. (Scores are mean per cent of time by exercise.)

[1] TASK PROCESS ACTIVITIES FOR EXERCISES 3 AND 4 COULD NOT BE SEPARATED

trainee attempting the fourth and fifth exercises experienced greater difficulties in learning or retaining the technical information and, after a period of inadequate achievement, began to refer more frequently to this material.

These findings parallel those for the Flow Charting exercises, but the differences between aptitude groups are not as great. The Relative Motion task, while requiring the same kind of processing as did the Flow Charting task, did not impose as great a demand for the learning of technical information. Hence, differences in allocation of time to the various task processes are reduced relative to the flow charting task.

3. The Concept Attainment Task

Several of the task process activities employed in Flow Charting and Relative Motion were also found in Concept Attainment. The big difference was an expansion in task process activities in the category, Drafts Trial Aspect of Work Product. In the Concept Attainment task the trainee must hypothesize different rules to find the rule determining a pattern of zeros and ones. To develop a classification system for the trial hypotheses would have carried us beyond the immediate goal of the study. The difference between Concept Attainment and the other tasks makes it clear that a problem-solving process can be specific to a type of problem-solving task.

F. Discussion

This intensive study of a few individuals has developed insight into the manner in which trainees go about learning to solve Flow Charting problems. Generalization of the findings involving so few subjects must, of course, be made with caution. Nonetheless, certain points seem clear.

First, Meyer's (1965) finding that Mathematical Aptitude is an important factor in this kind of learning is clearly confirmed. Furthermore, trainees with low aptitude in both verbal and mathematics scores simply got nowhere with these problems. It is a moot question whether any method of training will do much for this group. The implication is that there must be a really important reason to undertake the effort of training them in this kind of problem solving.

Second, the value of Flow Charting for computer programming purposes for the study of problem solving activity is evident. For three of the problem solving tasks--Reading Comprehension, Hypothesis Evaluation, and Number Base Arithmetic (including symbol manipulation)--there was insufficient observable activity, despite serious effort to evoke it, to be able to know what the trainee was doing. Both the Relative Motion and the Flow Charting tasks did evoke sufficient observable behavior but the Relative Motion task did not produce sufficient variation in relation to aptitude for the purpose of studying the importance of compatibility of learning with the trainee's general mode of learning.

Some examples of the application of this approach are presented in Table 5 to show the manner in which the Flow Charting and Relative Motion tasks can be analyzed into these kinds of learning. Future work should examine the merits of this approach for its value in developing training programs. Such factors as the time required for the subjects, the tremendous effort that is required in the observation and recording of trainee activities in problem solving, and the inability to observe what is really going on in many instances point to the support required for future studies. The computer is, of course, the tool par excellence for keeping track of an enormous number of responses and sequences. Further effort in the study of problem solving processes will be deferred until an installation including a computer-driven student instruction station with appropriate input and output modes and operated on a time sharing basis is available.

The Concept Attainment task does produce observable activity. But it is quite evident that a substantially different manner of classifying the task process activities is required. This observation answers one of the questions with which the study started: Are there different processes for different tasks? There are, and this means that conclusions concerning problem solving studies must be confined to the type of problem studied--a third finding of the study.

The classification of task processes used in categorizing behavior for the Flow Charting and Relative Motion exercises was inductively derived. Protocols were studied and the classification developed. The percentage of task completion time devoted to each activity by an individual indicates when he is progressing satisfactorily. When the proportion of a trainee's responses in the category, Initiates and Develops Solution declines, one can be sure he is having difficulty. The related increase in the category, Obtains Technical Instruction, is indicative of the same thing.

One direction future studies might take is to classify problem-solving responses in terms of the requirements for supporting types of learning (i.e., for aspects of the task process). The classification proposed by Gagné (1965) and mentioned earlier in this paper indicates a number of supporting types of learning, and the implication is that mastery of terms, concepts, etc., at the subordinate levels must be achieved before problem solving can be successful.

When an individual is confronted with a "new" problem-solving task, learning of the supporting capabilities should be facilitated and solution efficiency increased, if the individual's aptitude profile indicates high competence in those aptitudes which are compatible with the requirements of learning of the supporting capabilities. Similarly, learning should be impeded if the new problem solving task requires the acquisition of capabilities incompatible with the available aptitudes. Many different areas of learning and aptitude characteristics may be involved in different instances of compatibility and incompatibility.

Analysis of task process activity patterns based on this hierarchical concept of types of learning should permit the detection and diagnosis of learning problems at subordinate learning levels rather than at the gross level of "failure to learn to solve this type of problem." It should be possible to treat the learning problem in the more delimited context of specific subordinate types of learning, e.g., principle X, concept A, multiple discrimination D, etc. Patterns of task process behavior may reflect or be symptomatic of more localized difficulties in acquiring certain subordinate types of learning. If the high peaks in aptitude profiles function as facilitators (mediators) of such subordinate learning items, it should be possible to tailor highly specific learning materials to capitalize upon the available mediators. It must be recognized, however, that the success of this approach will be limited by the extent that aptitude influences the acquisition of the higher order skills independently of the acquisition of the lower order skills.

Some examples of the application of this approach are presented in Table 5 to show the manner in which the Flow Charting and Relative Motion tasks can be analyzed into these kinds of learning. Future work should examine the merits of this approach for its value in developing training programs. Such factors as the time required for the subjects, the tremendous effort that is required in the observation and recording of trainee activities in problem solving, and the inability to observe what is really going on in many instances point to the support required for future studies. The computer is, of course, the tool par excellence for keeping track of an enormous number of responses and sequences. Further effort in the study of problem solving processes will be deferred until an installation including a computer-driven student instruction station with appropriate input and output modes and operated on a time sharing basis is available.

TABLE 5

Examples of Levels of Learning in Flow Charting and Relative Motion Problems

Exercise Solution and Level of Supporting Type of Learning	Examples	
	Flow Charting	Relative Motion
Problem Solution (or Design)	A flow chart instruction which reads as follows: $\boxed{(X) + (Y) \rightarrow Z}$	Change in own position to be made so that bearing and range to new location of Ship X are same as before Ship X maneuver.
Principles	Concepts in Solution operate as stated in Verbal Chaining.	Distance covered equals speed multiplied by time.
Concepts	$\rightarrow Z$ means, "Transfer (some quantity) into cell Z."	Range, bearing, time, and speed.
	( ) means, "Value within is address of number to be used in computation."	Changes and sequences of change in all other concepts.
Multiple Discriminations	Transfer and Compare are mutually exclusive operations and are coded accordingly.	Learn to discriminate a true movement vector from a relative movement vector.
Verbal Chaining	"Add quantity in cell X and quantity in cell Y and transfer the sum to cell Z."	Describes the basic principles and concepts for solution, as, "Distance equals speed multiplied by time."
Stimulus-Response Motor Chaining	Write X, Y, Z, ( ), $\rightarrow$, and	Use compass rose, dividers, and parallel rulers; write.

Note.--These examples are illustrative only, and are not intended to present a definitive or exhaustive list.

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Gagné, R. M. *The conditions of learning.* San Francisco: Holt, Rinehart, and Winston, 1965.

Meyer, J. K. An experimental comparison of instructional techniques for use in teaching computer program flow chart design. *U. S. Naval Personnel Res. Act., San Diego, Tech. Bull. 65-10,* March 1965.

APPENDIX A

TASK DESCRIPTIONS OF PROBLEM SOLVING TASKS FROM WHICH USABLE PROCESS DATA COULD NOT BE OBTAINED

1. Number Base Arithmetic Task

This task required the trainee to read exercises in transforming expressions of quantity (i.e., "numbers") from a system in one base (such as Base Ten in the decimal system) to another ase, and find the answers by reading a textbook chapter telling how the answers are to be found. The response modes involved verbal comprehension and operations with algebraic symbols.

2. Concept Formation Task

This task was to discover a rule determining the presence or absence of an unknown pattern in a series of presentations consisting of five horizontally aligned positions each containing a one or a zero (for example, 0 0 1 0 1). After responding to each presentation, the trainee was told whether the presentation did in fact manifest the pattern or not and marked the presentation accordingly (red for "Yes" and green for "No"), and results of previous presentations remained on display. The trainee was permitted to stop after answering ten consecutive presentations correctly and giving the correct verbal definition for the pattern. A separate pattern was used for each of several exercises. Up to 32 presentations were available for each exercise.

The inputs were visual. The response mode involved repeated use of specific logical and symbolic operations. The trainee was not given patterns to evaluate, but had to derive a pattern concept for himself from the presentations.

3. Hypothesis Evaluation Task

This task required the trainee to evaluate the relation of given inferences to printed scientific text information. A text paragraph on a scientific topic was first read, and then followed by a series of stated hypotheses about the phenomena presented.

The response mode was verbal inference, although the information involved experiments and occurrences in physics. As in the case of Concept Formation, the response mode also clearly involved logic in examining many presentations to see whether a given principle applied.

4. Reading Comprehension Task

The trainee was required to read a passage of a few paragraphs of general literature and answer multiple choice questions while the paragraph was still fresh in his mind. Duration was adequate for the trainee to re-examine the paragraph in order to search for answers to the questions. Three passages were used. The response mode was verbal comprehension.

LIST OF APTITUDE TESTS

Subtests of Naval Officer Classification Battery:

Mathematics
Verbal Reasoning
Relative Motion of Ships

Experimental Programmer Aptitude Tests constructed by the Department of Psychology at the University of Southern California:

Operations Sequence
Symbol Grouping

Educational Testing Service, Princeton, New Jersey:

Co-op English Tests, Form 1A:
- Reading Vocabulary
- Reading Comprehension

APPENDIX B

APTITUDE PROFILES OF THE TRAINEE GROUPS

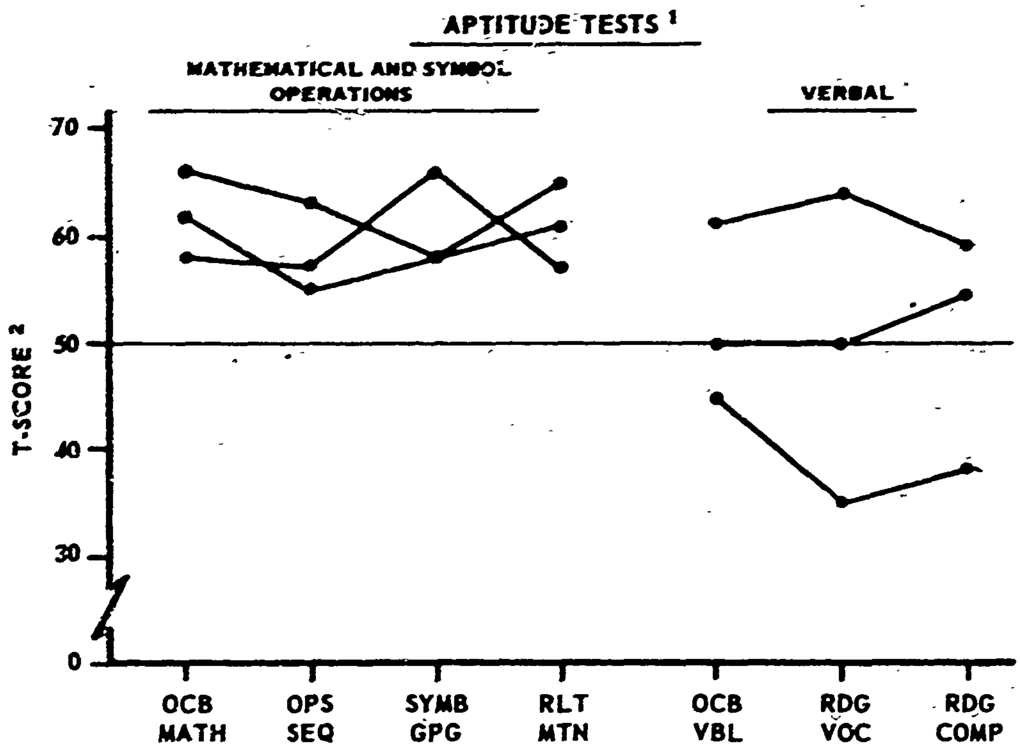

Fig. 11. Aptitude profiles of the three trainees in the High Mathematics aptitude group.

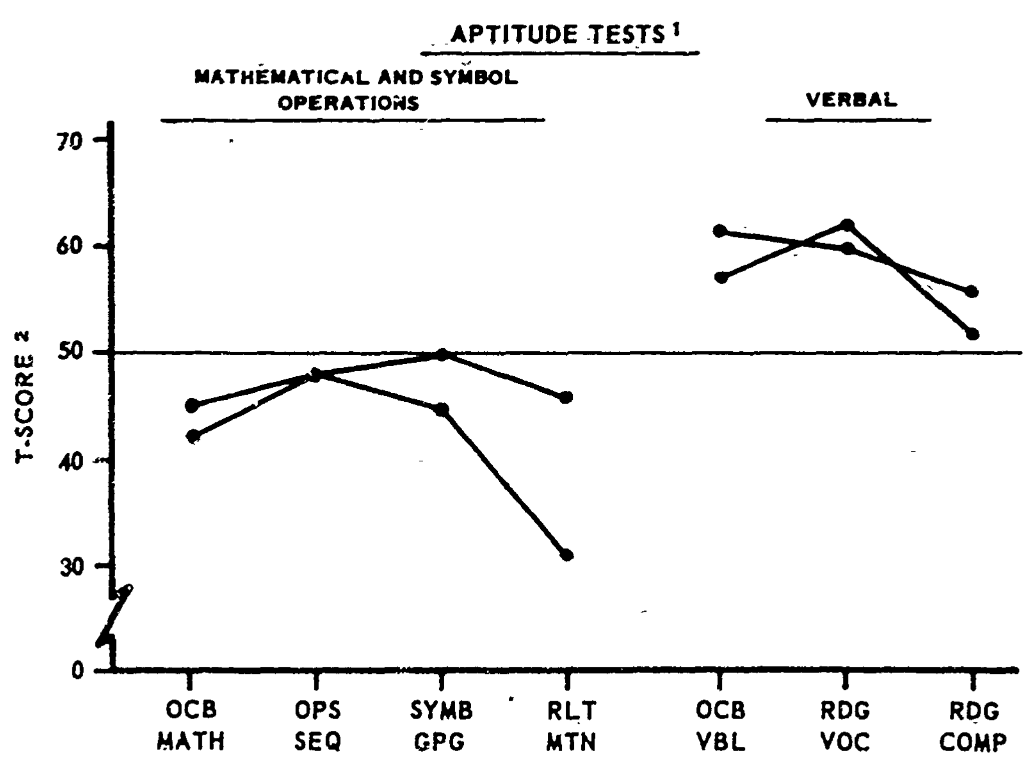

Fig. 12. Aptitude profiles of the two trainees in the High Verbal aptitude group.

[1] THE APTITUDE TESTS ARE LISTED IN APPENDIX A

[2] MEAN IS 50 AND STANDARD DEVIATION IS 10

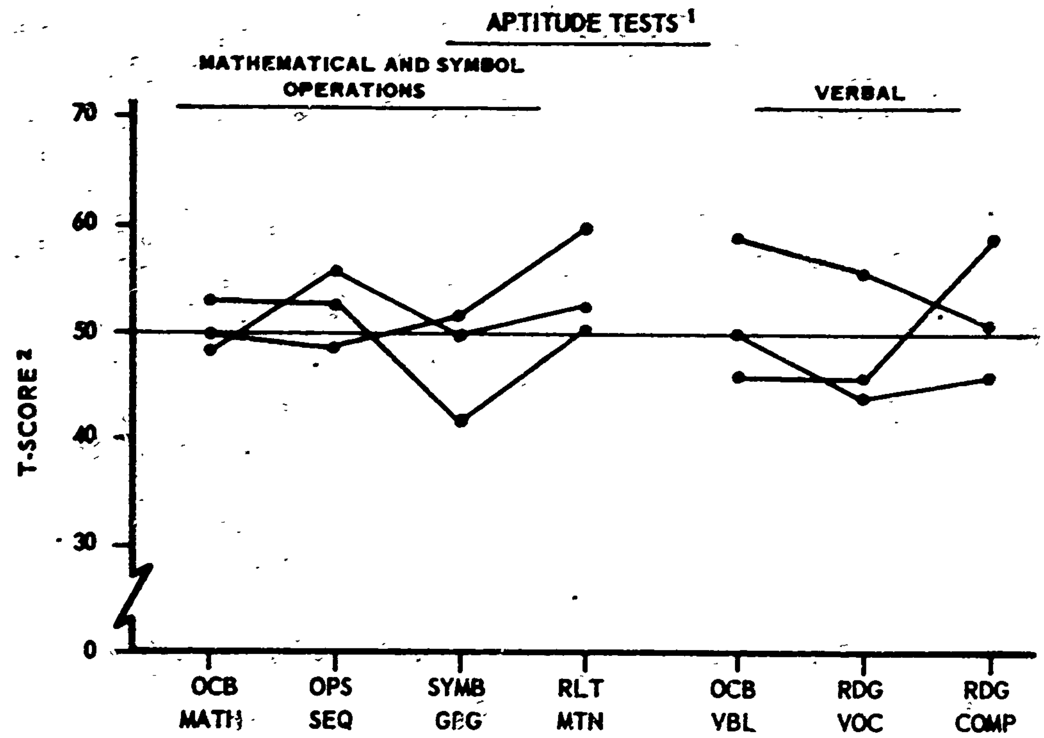

Fig. 13. Aptitude profiles of the three trainees in the Intermediate aptitude group.

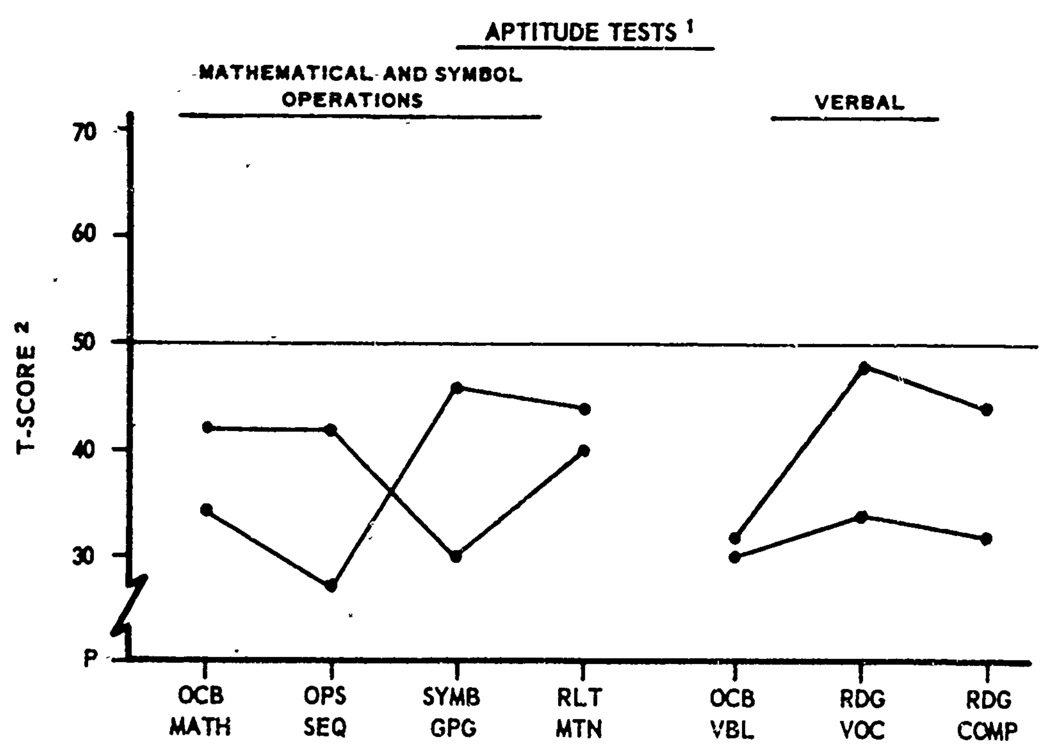

Fig. 14. Aptitude profiles of the two trainees in the Low aptitude group.

[1] THE APTITUDE TESTS ARE LISTED IN APPENDIX A

[2] MEAN IS 50 AND STANDARD DEVIATION IS 10

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13. ABSTRACT

~~This was an~~ exploratory study aimed at developing methods and hypotheses about how individuals solve complex problems involved in Navy instruction. Particular attention was given to instances where individuals were required to solve problems with requirements that were inconsistent with their most highly developed skills and aptitudes, e.g., individuals with high verbal aptitude required to solve problems which were mainly mathematical in nature.

For only three of the six types of problems used in the study was it possible to observe and categorize the problem-solving activity. One purpose of this study therefore--comparison of problem-solving activity across tasks of different types--could not be achieved. Among three types of problem for which processes were observable and could be categorized, the processes for one, Concept Attainment, were sufficiently different from the other two to make clear that problem-solving strategies vary from task to task and may even be specific to a single type of task.

For two tasks, Flow Charting and Relative Motion problems, responses were categorized in a manner descriptive of the processes used in working on them. Major findings were the marked differences in approaches or strategies for solving these problems by groups differing in verbal-mathematical aptitude patterns. Different training methods will need to be developed for these groups to maximize efficiency in teaching this kind of problem solving. The time required to code and analyze responses in this kind of study require that further work in this area be deferred until a properly programmed and equipped computer is available for keeping track of trainee responses.

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